

Modeling the Formation and Offshore Transport of Dense Water from High-Latitude Coastal Polynyas

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LONG-TERM GOALS

Our long-term goal is to understand the role that dense water, formed on high-latitude continental shelves, plays in the thermohaline circulation of the Arctic Ocean and the maintenance of the mean hydrographic structure of the deep Arctic basins, e.g. the upper halocline.

OBJECTIVES

Our immediate objective is to improve our basic understanding and ability to predict (1) the formation and offshore transport of dense shelf waters formed beneath high-latitude coastal polynyas and (2) the pathways by which dense shelf waters enter the deep basins.

APPROACH

Our hypothesis is that dense water, formed beneath coastal polynyas, is transported across the shelf via small-scale (15-25 km) eddies (e.g. Gawarkiewicz and Chapman, 1995; Chapman and Gawarkiewicz, 1997; Chapman, 1999; Gawarkiewicz, 2000). These dense water eddies are capable of moving offshore across the shelf break and into the deep basins where they contribute to the maintenance of the observed thermohaline structure. We are testing this hypothesis with a combination of (1) process-oriented numerical modeling, (2) analyses of historical observations, and (3) numerical modeling of realistic coastal polynyas.

WORK COMPLETED

(1) A study has been completed (Chapman, 2000) that examines the effects of a steady background alongshelf current on dense water formation and transport from an idealized coastal polynya, as well as the influence of a submarine canyon located downstream from the polynya.

(2) A comparison of model scales with those inferred from observations over the Chukchi Shelf (from Dr. Tom Weingartner, U. Alaska-Fairbanks) is nearly complete.

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(3) Regional models of the areas of polynya activity on the Chukchi Shelf (along the north coast of Alaska) and St. Lawrence Island have been constructed, with realistic coastlines and topography.

(4) A study has begun of the interannual variability of dense water production from polynyas on the Chukchi Shelf over the past 20 years.

RESULTS

(1) An ambient alongshelf current does not change the basic ocean response to polynya forcing, but it dramatically alters the direction of dense water transport by carrying the dense water along the shelf. It also changes the density distribution of dense water produced; reducing the maximum density anomaly created but increasing the volume production of dense water. The ambient current may also steer the dense water around a submarine canyon, such that little or no dense water flows down the canyon unless the canyon is oriented nearly parallel to the coast.

(2) Observations near the central Chukchi Shelf suggest very large variability in the salinity and velocity fields. Salinity variations are 1.5 PSU or larger, with changes occurring on time scales of a few days. Associated with these large changes in salinity are velocity fluctuations of 20 cm/s. Our numerical model can reproduce these scales, but only with a relatively shallow region adjacent to the coast, and only if bottom friction is much less than typical of mid-latitude shelves.

(3) We have constructed models with realistic coastlines and bottom topographies for the Chukchi Shelf and St. Lawrence Island and have examined the response to simple polynya forcing to get some idea of the pathways that dense water may take in crossing the shelves. The importance of realistic bathymetry in steering the dense water eddies is clearly evident, i.e. the paths taken by the dense water eddies are quite different over a flat bottom.

(4) We have forced the numerical model in an idealized configuration with polynya forcing (size and buoyancy flux) computed by Peter Winsor (Goteborg U., Sweden) for each winter from 1978 to 1999, based on estimates from the National Center for Environmental Predictions (NCEP). This produces estimates of dense water production and density distribution of modified waters for each year. The results show enormous interannual variability in both volume of densified waters and the maximum density anomaly created.

IMPACT/APPLICATIONS

Our results suggest that the offshore transport of dense shelf water is highly sensitive to variations in shelf topography and the presence of ambient shelf currents. There is no obvious place that we can expect to find dense water leaving the shelf, and this should be taken into account when designing a field program to observe shelf-basin interactions. Our numerical models are useful tools for understanding the processes associated with dense water formation and offshore transport from coastal polynyas.

TRANSITIONS

There are no transitions at this point.

RELATED PROJECTS

We are working closely with Tom Weingartner (U. of Alaska, Fairbanks), Don Cavalieri (Goddard Space Flight Center) and Thorsten Markus (U. of Maryland) in the examination of historical observations from the Chukchi Shelf and the realistic modeling of this region. We are also working closely with Knut Aagaard (U. of Washington), Tom Weingartner and Seelye Martin (U. of Washington) to develop a realistic model of the St. Lawrence Island polynya in conjunction with the field program that has recently taken place there.

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